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PHYSICAL FOUNDATIONS OF LASER TECHNOLOGYFORMATION OF TYPES OF VIBRATIONS

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Abstract: This topic discusses the physical foundations of laser technology and the formation of the types of vibrations that occur in it. The basic conditions necessary for the formation of a laser are considered - the energy levels of atoms and molecules, stimulated emission, population inversion, etc. It also provides an understanding of how various vibrations are formed: mechanical, electromagnetic and molecular vibrations, and what role they play in the operation of a laser. This topic studies the basis for the stability, narrow focus and high-frequency properties of laser radiation. At the same time, clear and understandable information is provided about the principles of operation of laser devices and their relationship to vibrations. The topic is theoretically important and of great importance in understanding practical laser technology.

Keywords: formation of types of oscillations, spontaneous or forced radiation, absorption of light, kwind generator, properties of laser light, monochromaticity, coherence.

Introduction

In recent years, laser technology has achieved unprecedented development in various fields of science and technology. In particular, the specific properties of laser radiation - high precision, narrow focus, monochromy and high energy density - have led to its widespread use in medicine, industry, information technology, military equipment, geodesy and scientific research. The basis of such opportunities lies in the physical nature of the laser, that is, in the mechanisms of radiation generation. Laser radiation occurs not randomly, but based on specific physical laws. In this process, the role of changes in the energy levels of atoms and molecules, the phenomenon of stimulated emission, population inversion and resonator systems is invaluable. At the same time, the types of vibrations generated in lasers - that is, vibrations at the electromagnetic, mechanical and quantum levels - are one of the important parts of these processes.

This topic discusses these physical processes, in particular, the formation of vibrations and their importance in generating laser radiation. The topic provides the necessary knowledge for in-depth study of the theoretical foundations of laser technology, a proper understanding of its practical possibilities, and future scientific research in this area.

The use of light energy has been a long-standing dream of mankind. Since ancient times, the sun has been considered a source of light radiation. However, solar radiation, like the radiation of heated bodies or the discharge of electric gas, is polychromatic, that is, a mixture of waves of different lengths.

With polychromatic radiation, atoms are excited and move from a higher energy level to a lower one, accompanied by the emission of electromagnetic vibrations. This radiation is carried out in the form of individual particles - quanta (photons). The energy of a photon is equal to the difference between the energies of the atom in the higher and lower states and can be determined by the formula

$E=h\nu$

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where h is Planck's constant; ν is the frequency of the radiation, Hz.

Under normal conditions, atoms of matter emit photons of different energies, and the transition of atoms from one energy state to another is random. The radiation that appears in this case is a set of wavelengths of different lengths, that is, it is polychromatic.

Further technological use of polychromatic radiation requires focusing it to increase its energy concentration. However, after the polychromatic radiation passes through the lens, the focused spot has very significant dimensions, which is explained by the different refractive indices of different wavelengths.

It is known from the theory of optics that the size of the focal spot is determined by diffraction, and its minimum size is approximately equal to the wavelength of the focused radiation. Thus, it is in principle possible to focus radiation with a wavelength in the optical range to a spot with a size of about 1 μm. However, due to polychromaticity, the size of the focused radiation at the spot increases to hundreds and thousands of micrometers. As a result, it is impossible to obtain a high concentration of the energy of polychromatic radiation.

The main solution to the problem is to obtain monochromatic radiation of a certain wavelength in the range of light radiation 0.1-10.0 μm. Such radiation was obtained in 1960 in an optical quantum generator (OKG), which used synthetic ruby as a working fluid. Later, OKG received the name "laser" from the first letters of the English expression (light amplification by induced emission).

Metodology

The operation of a laser, as its name suggests, is based on the principle of stimulated emission. To understand the principle of stimulated emission, it is necessary to look at the elementary foundations of quantum electronics. The internal energy of atoms and molecules can take on a whole range of fixed values, characteristic of a given type of atom and molecule. In Figure 1, two energy levels E1 and E0 can be seen. The transition of an atom from a higher level to a lower level is accompanied by the emission of a photon. The energy of this photon is equal to the difference between the energies of the atom in the higher and lower states. If the atoms do not experience any external influences, then they are in a state that can be called equilibrium. This state means that, despite the chaotic motion of the atoms, the number n of their higher and lower energy states does not change. In addition, according to Boltzmann's principle, the number of atoms in the lower energy state E0 is always slightly greater than the number of atoms in the higher state E1.

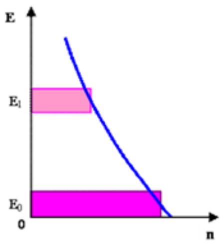

Figure 1. Equilibrium state diagram of a two-level nuclear energy system

Each atom in the lower energy state E0 can move to the higher energy state E1 by absorbing a single photon. Accordingly, each atom in the higher state E1 gives up excess energy in the form of the same photon and moves to the E0 level.

The equilibrium state is conditionally shown in Figure 1. It is provided by the spontaneous emission of a photon, which occurs independently of external influences and is accompanied by the transition of the atom from a higher energy state E1 to a lower E0.

The effect of additional external energy, i.e. heating, transfers some of the atoms to a higher energy state, and when they move to a lower state, they emit photons. However, this radiation of atoms occurs independently of each other. Light quanta are emitted by atoms in chaotic motion. Spontaneous

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radiation is observed. Along with the emission of photons by atoms located in the higher E1 level, energy is absorbed by atoms located in the lower E0 level. In this case, the atom absorbs a photon, which prevents the occurrence of radiation, rising to a higher E1 level.

To produce radiation, the number of atoms in the higher E1 level must be greater than the number of atoms in the lower E0 level. Under natural conditions, at any temperature, there are always fewer particles in the higher level than in the lower level. Special measures are taken to ensure that the higher of the two levels under consideration is more crowded than the lower. This state of matter in quantum electronics is called an active medium with inverse coupling.

There are various methods for creating radiation inversion, which depend on the specific energy level scheme and the properties of the active particles. It is possible to see the creation of inverted radiation in a three-level energy system using optical effects. Using this scheme, monochromatic radiation was first obtained in a ruby laser.

In the absence of external influences, i.e., in the absence of rest, the distribution of atoms in the state obeys Boltzmann's law (Fig. 2a). The transition from the E1 state to the E0 state occurs according to the previously considered two-level scheme and is a transition that prevents the production of radiation. Under the influence of external energy, for example, the optical action of a xenon lamp, the active medium intensively absorbs energy. As a result of absorption, a large number of atoms can move to the highest energy level E2, and from there spontaneously to the E1 level (Fig. 2, b).

A sufficiently intense optical pulse causes a significant number of atoms to transition from the ground state to the E1 level and exceed the excitation in the E0 ground state. This state is described as excitation inversion (Fig. 2, c). The subsequent transition of atoms from the E1 level to the E0 ground state occurs with the appearance of laser radiation. This transition leads to induced, i.e. forced, radiation. There are other systems for obtaining radiation inversion. In particular, a four-level system for obtaining inverted radiation is widespread for the following active laser particles: CO2 molecules, CO in gas lasers, neodymium ions in solid-state systems, etc.

Creating a reverse arrangement of active particles is the main condition for obtaining laser radiation. In modern technological lasers, various gas mixtures, solids and liquids are used as the active medium, called the working fluid.

The working fluid of an optical pump is supplied with a light flux from a pulsed or continuously operating gas discharge lamp. This pumping method is used to excite lasers in which the working fluid is a solid or liquid.

In the gas discharge pumping method, active particles of the working fluid are exposed to an electric discharge. This pumping method is widely used to excite lasers in which the working fluid is a mixture of various gases.

The energy transfer considered in the form of induced (forced) radiation is the basis of the operation of optical quantum generators - lasers. The laser is a source of radiation directly excited inside it. The diagram of a laser consisting of two necessary components - the active medium in the resonator is shown in Fig. 3. The active medium 2, in accordance with the conditions considered above, has reverse radiation. The optical resonator consists of one flat transparent mirror 1 and a flat mirror 3 parallel to it, transmitting radiation with partial transparency.

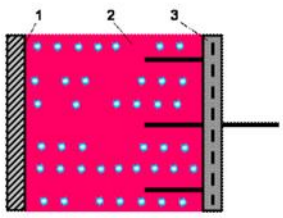

Figure 3. Schematic diagram of a quantum generator

To carry out the generation process, part of the emitted light energy must constantly remain inside the active medium, which should cause the excited radiation of new atoms. This condition is precisely fulfilled using an optical resonator mirror (Fig. 3). Mirror 1 reflects all the energy falling on

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it, and transparent mirror 3 transmits only a part of the energy, that is, the useful energy. Then this part of the energy is removed from the resonator, and using focusing systems, the light radiation is concentrated to a small spot to obtain a high power density. Part of the energy is reflected in the resonator through a transparent mirror 3 and serves to attract new parts of the active medium to the generation.

Thus, in a quantum generator, using an optical resonator, the high radiation intensity necessary for the effective implementation of induced radiation processes of excited particles of the laser active medium is obtained. Optical resonators not only significantly increase the probability of induced forced processes, but also determine the properties of laser radiation.

Industrial lasers used for material processing produce radiation with a wavelength of approximately 0.1–10.6 µm (mainly in the ultraviolet and infrared regions). Depending on the operating modes, a distinction is made between continuous and pulsed periodic lasers. The main properties of laser radiation that ensure its practical application are monochromaticity, high coherence, low radiation divergence, and high radiation power density.

Result and Discussion

Monochromatic lasers characterize the ability to emit in a narrow range of wavelengths. Monochromatic radiation is obtained using monochromators. Their principle of operation is to separate a narrow frequency range from a certain spectrum of thermal radiation. This method of obtaining monochromatic radiation, which is associated with large power losses, has not found application in industry. Unlike monochromators, a laser can create very large energy and radiation power in a very narrow range of wavelengths. In practice, a laser is emitted at the same wavelength.

Laser radiation is characterized by coherence, which is easier to understand than ordinary polychromatic radiation. Polychromatic radiation, which is characteristic of heated bodies, consists of a set of waves of different frequencies, the phases of which change chaotically over time and is a typical example of coherent radiation. In contrast, the energy of laser radiation, accumulated in an optical resonator, is formed in such a way that the newly formed radiation is in phase with the one that propagates in space. Such radiation is described as coherent.

Due to its monochromaticity and coherence, laser radiation can theoretically be focused into a spot with a diameter corresponding to the wavelength of the radiation. This achieves the high concentration of radiation energy necessary for efficient processing of materials.

A valuable property of laser radiation is its high directivity, characterized by low divergence of radiation. Theoretically, the angular divergence of laser radiation can be so small that it is determined only by the phenomenon of diffraction of coherent waves at the exit of the beam from the resonator. The practical divergence of laser radiation significantly exceeds the theoretical divergence. But despite this, laser radiation has a very high directivity compared to conventional light sources. Due to the low divergence, laser radiation is focused to a small spot, which provides a high concentration of energy. The high directivity of laser radiation allows laser energy to be transmitted over long distances with very low losses. The considered properties of laser radiation - monochromaticity, coherence and low divergence - make it possible to obtain high power densities. The power density of laser radiation E is the ratio of the radiation power passing through the cross-section of the laser beam to the cross-sectional area S, i.e. E = P / S The power density E is measured in W / cm2. The power density of laser radiation reaches enormous values due to the ability to focus laser radiation into a very small spot of tenths or hundredths of a millimeter. The creation of powerful technological lasers made it possible to achieve densities of up to 108 W / cm2 in continuous mode and up to 1012 W / cm2 in pulsed mode when focusing this radiation.

Conclusion

Such high energy parameters of laser radiation are several orders of magnitude higher than the power density of electric arc, plasma and other known sources of thermal energy, ensuring highly efficient and high-quality processing of any materials in the technological processes of hardening, surface coating, welding, cutting and drilling.

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